The Joan Pye Project

Energy for the next generation

JPP Technical Report:

Nuclear Waste Deposition and Disposal

A contribution to the nuclear debate from The Joan Pye Project – Autumn 2007

Hinckley Point Nuclear Power Station

Foreword

This brief explanation of the various levels of radioactive waste discharged from civil nuclear-power reactors, whether early models or more advanced types, is not a learned scientific paper in the usual sense. It was never intended for ‘peer review’ before publication, indeed the authors of the separate sections strenuously deny that they had any such intention. It is intended as a simple presentation of the facts for the instruction of the concerned lay members of the public who may be unfamiliar with these topics of a modern energy-hungry age.

Further enquiries, addressed to the co-ordinator of the Joan Pye Project, will be answered by experts in the appropriate field.

Joan M Pye, MA, FINucE(Hon)
Co-ordinator

Nuclear Waste Deposition and Disposal

The Joan Pye Project, set up in 2004 by a former member of the Harwell Atomic Energy Research Establishment, aims to promote public awareness of the policy issues relating to nuclear power. The Project's first report, summarised here, deals with the problem of handling and storing nuclear waste.

The technical problems involved have been well understood for at least a quarter of a century. The results of a detailed study were reported to Parliament as long ago as July 1982. That report (Cmnd 8607) made clear that the technology is well within the competence of modern engineering. But while other countries such as Sweden and Finland have since created repositories deep below ground, and while other countries are planning to follow suit, successive British governments have failed to establish any long-term policy. Meanwhile the British nuclear industry has been storing its radioactive waste above ground. This is a necessary interim phase that allows much of the radioactive heating to die harmlessly away. But the time has come when the next step would be to move the fuel into long-term repositories, tailored to the specific problems of handling safely the various kinds of radioactive waste. Unfortunately, when the long-awaited report of the Government Committee on Radioactive Waste Management (CoRWM) appeared in July 2006, it hardly amounted to an urgent call for action, though it did endorse deep geological disposal. The Committee could have done much more to establish a firm policy, and also to improve public understanding of the various processes that would be involved.

Source	HLW m^3	ILW m^3	LLW m^3
JPP	5,000 unconditioned	250,000	1,500,000
CoRWM	Combined 470,000		1,510,000
DEFRA	2,150	70,000	1,008,000

Table to show the variance in waste volumes as determined by JPP, CoRWM and DEFRA.

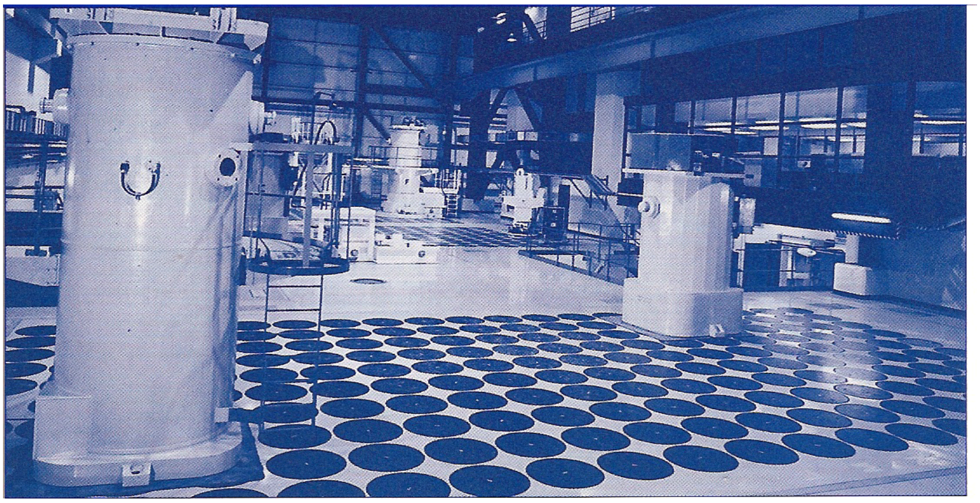
The Committee did the nuclear industry a disservice by the headline-catching statement that the total waste would occupy a space 'five times the volume of the Albert Hall' – 470,000 cubic metres. This sweeping generalisation, which was eagerly taken up by opponents of nuclear power, takes no account of the enormous differences of provenance, chemistry and half-life between the various kinds of radioactive waste – and incidentally includes as 'waste' materials the uranium and plutonium that are later reprocessed and reused. Against this background The Joan Pye Project invited a panel of nuclear experts to explain in clear and simple terms just what long-term storage would involve. CoRWM chose (for political purposes) to roll together all the waste from spend fuel element whether it was HLW, ILW or LLW. Only 5% (the fusion products) can fairly be classed as HLW: this amounts to the volume of one Albert Hall, not five Albert Halls. The rest is not waste but will be used again as new fuel (U and Pu).

NB: *"High level wastes are predominantly fission products from fuel processing, whilst the intermediate wastes are irradiated materials and medical and laboratory wastes. Low level materials are the general waste contaminated at very low levels."*

It is convenient to think of radioactive waste in three groups, conventionally described as High Level, Intermediate Level and Low Level wastes. These categories can be defined in terms of their specific radioactivity; but it may be more generally understandable to categorise them according to the kind of materials of which they are composed.

High Level Waste (HLW)

HLW arises directly from the used nuclear fuel that has been withdrawn from a reactor during a routine refuelling operation. It contains all the waste products of the fission process, which, because of their intense radioactivity, generate considerable quantities of heat which have to be dissipated by special cooling processes. This radioactivity decays slowly with time. Thirty years after removal from a reactor the level of radioactivity, and of consequent heating, is only half of what it had been one year after removal. The volume of this waste in the UK is less than five thousand cubic metres, even before volume reduction treatment. Some of it is in the form of glass bricks, a process known as 'vitrification'. The total volume of such waste amounts to about one lorry-load per year.



The Vitrification Plant Product Store, built to hold containers of highly active vitrified waste

Arguments about how long such wastes should be kept in storage, and therefore remain retrievable, have given way to a widespread international consensus amongst scientists and nuclear technologists that such wastes should go to geological disposal as soon as it is practicable for them to do so. Several countries are looking to disposal in repositories at depths of between 300 and 800 metres. Such repositories may be either 'wet' or 'dry'. Wet repositories are those below the water table, and may be in hard rocks like granite (as proposed by Sweden and Finland) or soft rocks like clays (Switzerland, Belgium, France). Dry repositories, which may have facilities for special recovery, are those above the water table (e.g. Yucca Mountain in Nevada, or are in salt deposits e.g. the Waste Isolation Pilot Plant in New Mexico). The best mined repositories are almost certainly adequate for the safe disposal of HLW. But even better options than 'wet' or 'dry' are available through very deep disposal (VDD), also known as borehole disposal (DBD).

DBD involves the permanent sealing of containers of HLW in the bottom of large diameter boreholes drilled 4 to 5 kilometres into the granitic basement of the continental crust. Three different versions of DBD, optimised for various waste types, are currently being researched at the University of Sheffield. Two are low-temperature versions, for wastes with relatively low heat generation. The third is a high-temperature scheme that deliberately makes use of the heat produced by some types of HLW.

After the waste packages have been deployed the borehole is backfilled and permanently sealed to ensure that there is no upwards return path for fluids. This is best accomplished by deliberate 'rock welding', through partial melting and re-crystallisation of the backfill and wall rock, either by electrical heating or by using the heat from heat-generating wastes. Decay heat from the waste gradually generates temperatures above 700 degrees C, which is sufficient to cause partial melting of the enclosing rock and backfill, and on solidification seals the waste packages into a 'sarcophagus' of solid granite. This creates a robust near-field containment. There is also the immense far-field barrier provided by over three kilometres of granite.

DBD offers advantages over other forms of geological disposal such as mined repositories, which should make it more politically and publicly acceptable. And since the cost of the boreholes is only about £4.5 million each, DBD is relatively inexpensive. Sufficient capacity to dispose of the UK's current inventories of spent fuel and other HLW could be drilled for less than £200 million.

DBD is extremely secure against terrorist attack or illegal misappropriation. Environmentally it is minimally disruptive. Deep drilling for scientific and industrial purposes has already created the necessary technology, which would only need re-scaling to provide the necessary combination of depth and size. Further details of the technology are available from Professor Fergus Gibb at the Department of Engineering Materials, University of Sheffield (email: fgibb@sheffield.ac.uk).

Intermediate Level Waste (ILW)

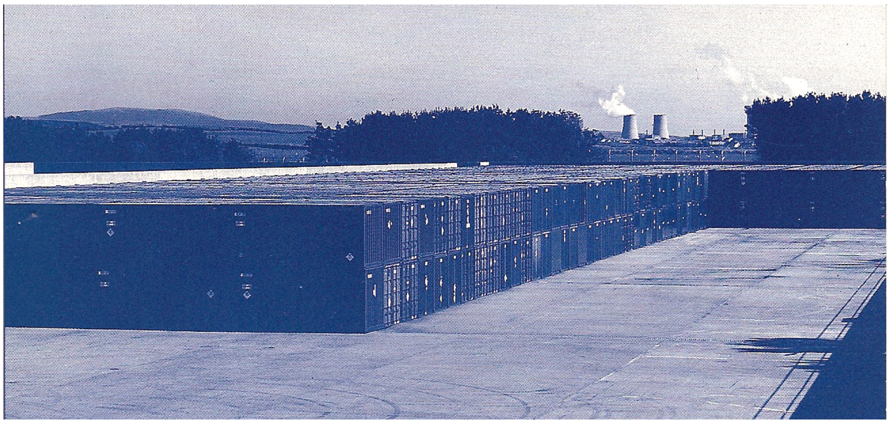
ILW arises from materials which have become radioactive through irradiation or contamination. They are principally the cladding material of the fuel and the structure of the reactor adjacent to the reactor core, plus a variety of other irradiated substances. Unlike HLW, the intensity of radioactivity from these sources is not sufficient to cause significant heating, but still poses a threat to health, and needs to be contained in a stable fashion, and stored in custom-built repositories. The requirements for shielding against radioactivity are however much less than for HLW. The well-established disposal route is to pack the waste into stainless steel vessels, the voids between pieces of waste being filled with specially formulated concrete. The containers can then be placed for long-term storage in a building where the activity can be allowed to decay harmlessly. Recent work in Japan has established that crushed concrete taken from reactor structures that are being demolished produces a suitable 'sand' for the manufacture of the infilling concrete – thus dealing with two sources of radioactivity at the same time. A further advance is the ongoing development of pulsed high-power microwave energy for the breakdown of concrete components, a process that does not give rise to the dust problems produced by jack-hammers and is unaffected by steel reinforcement.

During transport ILW packages require shielding because of high radiation levels; but once placed in final location ILW presents no hazard to the public.

Low Level Waste (LLW)

LLW arises from a variety of sources, but mainly comes from laboratory or workshop waste, together with material (e.g. hospital textiles) being disposed of by the medical profession. After treatment it still contains enough radioactivity to require storage, of a kind which keeps it separate from general and household rubbish. In volume terms it is by far the largest source of waste amounting annually in the UK to one and a half million cubic metres. There are some other wastes from the nuclear industry (VLLW) where the radioactivity is so low that they need not be distinguished from normal rubbish.

Low level waste has been stored by the British Nuclear Group near Drigg in Cumbria safely for many years, with no danger to humans or other life forms, ever since nuclear energy was first generated in the UK. Current waste volumes, according to BNG, amount to 950,000 cubic metres of packaged ILW. This is less than half the total capacity available. Extension of the storage facility in due course, as the site becomes full, is expected to pose too insuperable problem.



Retrievability – How Necessary?

Repositories (including sub-sea repositories accessed from land) from which stored fuel could, if necessary, be extracted at some time in the future, would be suitable for ILW and LLW, but not for unprocessed nuclear fuels and HLW. For the latter, as already explained, the only practicable solution would be very deep boreholes - 5km or more - in massive plutonic igneous rock without tectonic fracturing or shearing. Ideally such boreholes should be located on island sites where the facilities are designed to resist catastrophic events, such as glaciations or large-scale tsunamis of the scale that would result from the collapse of the volcanic edifice of La Palma. Such facilities would need to be protected against erosion, probably by being constructed underground. Building such a facility would be a huge challenge, though one not beyond the capabilities of major oil companies.

For HLW, spent fuel and a few other hazardous materials including military waste, retrievability would be out of the question. Their disposal must be permanent and irreversible. Once capped, the boreholes should not be capable of being uncapped. In contrast, with waste of lower radioactivity – ILW and LLW – retrievability would not be difficult, and might even be desirable for management purposes once the initial radioactivity had decayed.

Choosing and agreeing on the criteria defining the boundary between waste that could be regarded as retrievable – which implies a need for management – and higher-level waste where removal could not be permitted, is of course the central issue. A set of well-defined and preferably internationally agreed criteria needs to be developed. The criteria should include guidance on the acceptable geological properties of the host rock used for the permanent storage of HLW.

In Conclusion

The problems of safe storage and disposal of radioactive waste were fully considered and laid before Parliament more than twenty years ago. Solutions worked out at that time have since been implemented without leading to any serious safety problems. Despite the steady advance of this handling technology there remains a serious problem of misrepresentation by anti-nuclear organisations such as Greenpeace, Friends of the Earth, and the Sustainable Development Commission. One reason for their prominence in the public debate is the degradation of education standards in the UK. The lay public are ill-prepared to judge issues needing at least a moderate working knowledge of sciences like physics and chemistry, which in increasing numbers of schools do not even find a place in the curriculum. The public are consequently ill-prepared to judge whether there is a real problem with existing long-term storage of radioactive waste - which is why the Joan Pye Project has drawn attention to these ongoing developments, and to the promise which they show of being wholly successful.

The following authors contributed to this report:

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R H Phillips, formerly Senior Chemist, AERE Harwell (Intermediate Level Waste).

F Graham Brightman, formerly on staff of BNFL, Sellafield, Cumbria (Low Level Waste).

A list of references and of the panel members is available from the Editor, Joan Pye, at joan@joanpyeproject.org

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About The Joan Pye Project

The Joan Pye Project was initiated by Joan M Pye, FINucE(Hon) in December, 2004 with the purpose of bringing the views of experienced professionals to bear on the public debate concerning the future of nuclear energy in the United Kingdom.

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